CLAIMS

What is claimed is:

1. A fiber lens, comprising:
a graded-index lens;
a single-mode fiber disposed at a first end of the graded-index lens; and
a refractive lens having a hyperbolic or near-hyperbolic shape disposed at a second end of the graded-index lens to focus a beam from the single-mode fiber to a diffraction-limited spot.

2. The fiber lens of claim 1, wherein the hyperbolic shape focuses a collimated beam into the diffraction-limited spot.

3. The fiber lens of claim 1, wherein the near-hyperbolic shape includes a correction factor that compensates for beam curvature and allows focusing of a non-collimated beam into the diffraction-limited spot.

4. The fiber lens of claim 1, wherein a spacer rod is interposed between the refractive lens and the graded-index lens.

5. The fiber lens of claim 1, wherein a spacer rod is interposed between the graded-index lens and the single-mode fiber.

6. The fiber lens of claim 1, wherein a mode field diameter of the spot is less than 10 μm.

7. The fiber lens of claim 6, wherein the mode field diameter of the spot is in a range of approximately 2 to 5 μm.

8. The fiber lens of claim 6, wherein a working distance of the fiber lens is greater than approximately 5 μm.

9. The fiber lens of claim 6, wherein a working distance of the fiber lens is in a range from approximately 20 to 60 μm.

10. The fiber lens of claim 6, wherein a ratio of distance from a tip of the refractive lens to the beam waist to the mode field diameter at the beam waist is greater than approximately 5.

11. The fiber lens of claim 1, wherein a diameter of a core of the graded-index lens is in a range from approximately 50 to 500 μm.

12. The fiber lens of claim 11, wherein an outer diameter of the graded-index lens is in a range from approximately 60 to 1,000 μm.

13. The fiber lens of claim 1, wherein a relative index difference of the graded-index lens is in a range from approximately 0.5 to 3 %.

14. The fiber lens of claim 1, wherein an operating wavelength of the fiber lens is in a range from 250 to 2,000 nm.

15. A fiber lens, comprising:
a single-mode fiber; and
a lens disposed at an end of the single-mode fiber;
wherein a mode field diameter at a beam waist of a beam emerging from a tip of the lens is less than 10 μm and a ratio of distance from the tip of the lens to the beam waist to the mode field diameter at the beam waist is greater than 5.

16. The fiber lens of claim 15, wherein the lens comprises a hyperbolic or near-hyperbolic lens disposed at an end of a graded-index lens.

17. The fiber lens of claim 16, wherein a spacer rod is interposed between the hyperbolic or near-hyperbolic lens and the graded-index lens.

18. A method of making a fiber lens, comprising:
splicing a single-mode fiber to a graded-index fiber;
cutting the graded-index fiber to a desired length;
rounding a tip of the graded-index fiber into a hyperbolic or near-hyperbolic shape.

19. The method of claim 18, further comprising shaping the tip of the graded-index fiber into a cone or wedge having an apex angle defined by asymptotes of a hyperbola prior to rounding the tip of the graded-index fiber.

20. A method of making a fiber lens, comprising:
splicing a single-mode fiber to a graded-index fiber;
cutting the graded-index fiber to a desired length;
splicing a coreless fiber to the graded-index fiber;
cutting the coreless fiber to a desired length; and
rounding a tip of the coreless fiber into a hyperbolic or near-hyperbolic shape.